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March 21, 2000

Department of the Navy
Naval Radiation Safety Committee
Chief of Naval Operations (N-45)
ATTN: RDML L. Baucom
Chairman
Room 636
2211 S. Clark Place
Arlington, VA 22244-5108

SUBJECT: REVIEW OF SURVEY WORK PLAN FOR DEPLETED URANIUM (DU) PENETRATORS

Dear Admiral Baucom:

We have completed our review of the Navy's "Survey Work Plan for Depleted Uranium (DU) Penetrators, Vieques Naval Target Range, Live Impact Area, Vieques, Puerto Rico," provided by CDR G. Higgins on January 10, 2000.

In summary, the survey work plan appears sufficient for the Navy to proceed to locate and retrieve the depleted uranium rounds. We have provided four comments (Enclosure 1) that we believe the Navy should address before the survey is conducted. However, it is not necessary for the Navy to submit a response to the NRC. Our technical evaluation is provided in Enclosure 2. After the survey and retrieval of the penetrators, we request that the Navy submit a report documenting the results.

We do not consider the survey work plan to be a decommissioning plan necessary to demonstrate unrestricted release of the site. Any remaining penetrators (i.e., those not located or retrieved under this survey plan) and other residual contamination should be addressed in a future decommissioning plan.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and its enclosures will be placed in the NRC Public Document Room.

Should you have any questions concerning this letter, please contact us.

Sincerely,

/RA/

Mark S. Lesser, Branch Chief
Materials Licensing and Inspection Branch 2
Division of Nuclear Materials Safety

Docket No. 030-29462
License No. 45-23645-01NA

Enclosures: 1. Comments on Survey Work Plan for Vieques Naval Target Range
2. Technical Evaluation Report: U. S. Navy - Vieques Island Review of Survey Work Plan

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COMMENTS ON
SURVEY WORK PLAN FOR VIEQUES NAVAL TARGET RANGE

General Comment:

The Navy's Survey Work Plan presents a plan to: 1) perform a survey (it mentions a scoping survey and a final status survey), and 2) retrieve all detected penetrators. Staff from the Office of Nuclear Material Safety and Safeguards concludes that the proposed survey appears sufficient to locate and retrieve the depleted uranium rounds. This Navy Plan does not adequately address the issue of release, either restricted or unrestricted, as defined in Subpart E of 10 CFR Part 20. Therefore, following initial cleanup, the Navy should plan to submit a final decommissioning plan which addresses any unretrieved penetrators and other residual contamination.

Specific comments that the Navy should address prior to initiating cleanup:

1. What actions will the Navy take if a higher-than-background reading occurs and no penetrator is found? To what extent will the Navy investigate the higher-than-background? What will happen to material (e.g., soil, rocks, man-made material) with higher-than-background measurements with no associated penetrator? Will the Navy recover such material?

2. Once the location of the penetrator is found and removal of the penetrator is complete, at what level of contamination will the Navy decontaminate the soil/sand/fragments, if above-background activity is found? Since there is no concentration limit specified for this plan, where will the licensee stop digging or decontaminating the area surrounding the recovered penetrator?

3. In Section 10.5, the second sentence indicates the E-600 is operated in Gross Count Mode for photon energies between 60 and 200 keV. In Section 12.4, it states that the E-600/SPA -3 is calibrated to radiations within the approximate energy range of 60 keV to 2000 keV. The plan should clarify what energy range will be set during the actual survey, 60 - 200 or 60 - 2000 keV.

4. The Navy should consider the criterion for re-surveying an area that exhibits readings above background, as described in section 11.3. The plan should address initiating an investigation when the net count above background exceeds the critical level, rather than the MDA. The critical level in this case is about one half the MDA.

Enclosure 1

TECHNICAL EVALUATION REPORT
U. S. NAVY - VIEQUES ISLAND
REVIEW OF SURVEY WORK PLAN

INTRODUCTION

The U.S. Navy notified the U.S. Nuclear Regulatory Commission (NRC) on March 5, 1999, of an event involving depleted uranium (DU) ammunition. The survey work plan indicates that during a training exercise on February 19, 1999, two U.S. Marine Corps aircraft expended 263 DU rounds at the Vieques Island, Puerto Rico, North Convoy Site. The Navy indicated that a team of Navy health physicists was deployed between March 10 and 19, 1999, and recovered 57 DU rounds. Only a portion of the site was investigated at that time because of unexploded conventional ordinance and dense vegetation. The Navy plans to recover all detectable DU penetrators and conduct a final status survey.

The Navy submitted a Survey Work Plan in December of 1999. The purpose of the plan is to conduct a 100 percent survey of the area and remove all detectable DU rounds. This plan provides the following: (1) a history of the event, (2) a site description, (3) a summary of previous radiological investigations, (4) a summary of health effects associated with DU, and (5) a description of the planned survey methods.

DISCUSSION

This review is based on the information in the survey work plan and is divided into two areas: (1) detection of the DU, and (2) survey methods. In general, the survey work plan did not provide complete information. Therefore, we performed an independent analysis to support our review.

1. Detection of the DU Rounds

<u>Summary of Information Submitted</u>

Section 5 of the survey work plan describes the previous radiological investigation. The Navy used 2-inch x 2-inch sodium iodide (NaI) and pancake Geiger-Mueller (GM) detectors. The NaI detector was used for scanning. During this investigation, the Navy recovered 57 rounds, most of which were completely intact. The rounds were encountered at a spacing of 10 to 20 feet along the lines of fire, and about twenty percent of the rounds were on the surface. For rounds that were beneath the ground, the report estimates the average depth of six to eight inches, with a maximum depth of 18 inches. The work plan notes that “only a few holes exhibited residual contamination after the penetrator was removed. In these cases, part of the penetrator had fractured.”

The survey area will consist of approximately 10 acres (figure 3 of the survey work plan). The plan indicates that the actual affected area may be in the range of 1.5 acres, because the DU rounds are expected to be located along two firing lines. Two soil types (clay and sand) are expected to be encountered in the survey area. The background was estimated as 8,000 cpm and 3,000 cpm for the clay and sand soils, respectively. The survey work plan provides the following equation for the scanning minimal detectable activity (MDA):

$$L_d = 3 + 4.65\sqrt{B_i}\,\frac{60}{i}$$

where

L_d	net response level, in counts, that can be detected with a survey meter with a fixed level certainty
B_i	number of background counts in the scan interval
i	integrated scan interval in seconds

Actual MDAs are not reported. The survey work plan estimates a field of view of the detector of 5 inches in diameter for a penetrator buried at 9 inches. However, the basis for this estimate is not provided.

Staff Evaluation

DU consists of 99.8% uranium-238 (U-238), 0.2% uranium-235 (U-235), and 0.001% uranium-234 (U-234) [Ref 2]. The primary radionuclides that contribute to dose from DU are U-238 and its daughters with short half-lives[1], thorium-234 (Th-234), and protactinium-234m (Pa-234m). The minor amounts of uranium-235 (U-235) and lesser amounts of uranium-234 (U-234) do not contribute significantly to dose. Because the daughters of U-238 have significantly shorter half-lives, they are in secular equilibrium with the parent U-238. That is the U-238, Th-234, and Pa-234m are present at the same activity. Each round contains 148 grams of DU. Using a specific activity for DU of 4.3×10^{-7} Curies per grams (Ci/g) reported in U.S. Army Center for Health Promotion and Preventive Medicine report, “Radiological Sources of Potential Exposure and/or Contamination, TG-238” [Ref 2], each round contains 6.36×10^{-5} Ci total initial activity. U-238, U-235 and U-234 emit several alpha particles and several low energy gamma rays each. Th-234 emits four beta particles (average energies range from 19.5 to 50.6 keV) and several low-energy gamma rays (63.3 to 112.8 keV). Pa-234m emits three beta particles (average energies range from 410.2 to 825.4 keV) and several gamma rays (766.4 to 1001.0 keV). [Ref 3] The significance of these emissions relative to detection is discussed in the following section.

MARSSIM [Ref 1] provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys. These surveys involve sampling at discrete locations and performing non-parametric statistical tests to evaluate the data. Scanning is also performed to evaluate elevated measurements. MARSSIM is typically applied to residual contaminated areas (soil or building surface). Because the contamination at this site consists of predominately elevated areas (hot spots) that have a very small area, the statistical tests in MARSSIM are not strictly applicable.

The survey work plan presented an equation for the detection limit (L_d), but did not

[1]The time required for the activity to reduced by one half.

provide values for L_d. The detection limit is typically associated with sample counting. The expression for stating detection capabilities would be to use a minimum detectable concentration (MDC) for static measurements, or a scan-MDC for scanning measurements. The scan-MDC represents the minimum concentration above background that the scan survey instrument can distinguish from background. Methods for calculating the scan-MDC are presented in NUREG-1507, “Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions” [Ref 4]. Specifically the minimum detectable count rate (MDCR) in counts per minute can be calculated using the following equation.

$$MDCR = d' * \sqrt{b_i} * \frac{60}{i}$$

where

b_i	background counts in the observation interval
d'	index of sensitivity
i	observation interval (in seconds), based on the scan speed and areal extent of the contamination

The background count rate is 8,000 cpm for the clay soil. If we assume a one second observation interval and that the index of sensitivity is one, b_i is 133 counts and the MDCR is 692 counts per minute. For the sand soil, the background count rate is 3,000 cpm. If we also assume a one second observation interval and that the index of sensitivity is one, b_i is 50 counts and the MDCR is 424 counts per minute. These counts per minute are above background. It is not clear from the information provided how the background count rates were estimated (e.g., detector type, height above the ground). Background count rates should be determined using the survey instruments. Actual background count rates should be used to calculate the instrument MDCR. We have assumed that the reported background count rates are representative for purposes of our analyses.

The MDCR is used to calculate the minimal detectable concentration of a scan survey (scan-MDC) in disintegrations per minute (dpm) using the following equation.

$$Scan - MDC = \frac{MDCR}{\sqrt{p \varepsilon_i \varepsilon_s}}$$

where

p	efficiency of the surveyor
ε_i	efficiency of the instrument
ε_s	efficiency of the contaminated source

Because all the data are being recorded, the surveyor efficiency is one. The instrument efficiency is estimated by the Navy as 10 percent. The contaminated source efficiency is approximately 2 percent (i.e., 50 percent of the contamination will be emitted upward toward the detector and only 4 percent of the emissions are gammas). The scan-MDC for clay is calculated to be 3.46×10^5 dpm, and the scan-MDC for sand is calculated to be 2.12×10^5 dpm. As discussed above, the activity of one round is 6.36×10^{-5} Ci or 1.4×10^8 dpm. Based on this analysis and the data in figure 8 of the survey work plan, we conclude that the system will be able to detect rounds located on the surface.

Most of the gamma rays emitted by the DU have low energies. If the DU round is located beneath the ground surface, these gamma rays will be attenuated by the soil. To evaluate ability of the Eberline SPA-3 to detect the DU round beneath the ground surface, we used the information in NUREG-1507 [Ref 4]. The computer code SuperShield, version 1, was used to quantify the attenuation of the gamma rays. The gamma ray energies, flux (gamma rays emitted per second) and geometry of the shielding material (i.e., soil and air) are entered. The code calculates the exposure rate in roentgen per hour at a hypothetical detector. The spectrum of gamma ray energies and percent yield[2] were obtained from "Radioactive Decay Data Tables" [Ref 3]. The flux for each gamma ray was obtained by calculating the activity for each isotope and multiplying by the percent yield. The total initial activity of the DU round was calculated to be 1.4×10^8 dpm. As discussed above, the short-lived daughters of U-238 would also be present at this activity. Although U-235 is present at 1.39×10^6 dpm, it does emit a large number of weak gamma rays. Several of the gamma rays with small percent yields were combined with other gamma rays having similar energies. The gamma ray spectrum used in the analysis is summarized in Table 1.

Table 1. Gamma ray spectrum

Isotope	Gamma Ray Energy (keV)	Activity (dpm)	Percent Yield (%)	Emissions (dpm)	Emissions (dps)
U-238	66.4	1.4×10^8	0.1	1.4×10^5	2.3×10^3
U-235	109	1.4×10^6	1.6	2.3×10^3	3.8×10^1
	143.6	1.4×10^6	10.7	1.5×10^5	2.5×10^3
	163.3	1.4×10^6	4.7	6.6×10^4	1.1×10^3
	185	1.4×10^6	54.4	7.7×10^5	1.3×10^4
	202	1.4×10^6	6.39	9.0×10^4	1.5×10^3
Th-234	63.3	1.4×10^8	3.8	5.3×10^6	8.8×10^4
	92.6	1.4×10^8	5.4	7.6×10^6	1.4×10^5
Pa-234m	1000	1.4×10^8	0.6	8.4×10^5	1.4×10^4

The dose rate was calculated for DU rounds buried both in clay and sand at depths of 6, 9, 12, 18, and 24 inches. Both soil layers were modeled as concrete in the shielding code. For the clay soils a bulk density of 1.8 g/cm^3 was used, and for the sand soils a bulk density of 1.5 g/cm^3 was used. Because of the typically higher shear strength of the clay, it is anticipated that rounds would be buried deeper in the sand soil. For each of the simulations, a depth specific conversion factor was developed to convert µR/hr to cpm. Table 6.3 of NUREG-1507 provides an energy dependent conversion factor for a 2-inch by 2-inch NaI detector. The conversion factors were determined by multiplying

[2]Percent yield is the fraction of emissions that produce a gamma ray at a specific energy.

the dose rate for each gamma ray by the appropriate conversion factor from Table 6.3 and summing these products to obtain a depth specific conversion factor. As would be expected, the lower energy gamma rays are attenuated by the soil, and the depth specific conversion factor decreases with depth. Table 2 summaries the results of the SuperShield analyses.

Table 2. Summary of SuperShield Analyses

	CLAY			SAND		
Depth (in)	Exposure Rate (µR/hr)	Conv. Factor (cpm/µR/hr)	cpm	Exposure Rate (µR/hr)	Conv. Factor (cpm/µR/hr)	cpm
6	2.28	5,880	13,400	3.03	10,093	30,600
9	0.658	816	537	0.935	1,625	1,520
12	0.227	178	40.3	0.351	362.5	127
18	0.032	18.5	0.6	0.063	39.8	2.52
24	0.005	2.9	0.014	0.012	6.9	0.01

Comparing the estimated count rate at depth with the MDCR (i.e., 692 cpm for clay and 424 cpm for sand), we concluded that penetrators buried in either clay or sand will likely not be detected at depths greater than about 10 inches. If the penetrators are fragmented, the depth of detection will vary.

2. Survey Methods

<u>Summary of Information Submitted</u>

The proposed methods for conducting the recovery survey are presented in section 10 of the survey work plan. Three Eberline SPA-3 (2-inch x 2-inch) detectors connected to an Eberline E-600 multi-purpose digital survey instrument will be used. The survey instrument will be operated in gross count mode. The detectors will be mounted on a pushcart. The system will be calibrated with radiation within the approximate energy range of 60 keV to 2,000 keV with an accuracy of approximately 10 percent. The data will be transmitted using the NAVTRACK 2000 system. This system incorporates differential global positioning that is accurate to within 6 to 18 inches. Data will be recorded for each detector every second. A scan rate of 18 inches per second is proposed. Daily checks of the detectors and E-600 will be performed. In addition, the NAVTRACK 2000 operation will be checked daily to a quality control point at the start and end of each survey.

Background radiation levels will be established on-site from readings in the actual survey area. Because the contamination consists of discrete sources and is not uniformly distributed, the Navy proposes to use the survey area itself as the background area. Areas that exhibit readings above background will be re-surveyed with either hand-held instruments or the NAVTRACK system.

The survey work plan provides a health and safety plan, and procedures for detector calibration, gamma scintillation operation, and backpack, radcart and PC/master controller assembly. The plan also discusses the hazard from unexploded ordnance.

The data will be analyzed using the computer software available with the NAVTRACK system. Statistical information (high, low, mean, and standard deviation) will be calculated. A graphical review of the data will be performed using posting plots/maps and frequency plots/maps. An example of the system graphical output was provided for three penetrators located on the surface (Figure 8 of the survey work plan).

Staff Evaluation

The Navy should consider clarifying in the survey work plan the extent of a survey of an area after the penetrator is removed. The survey and remediation of the immediate area around a recovered DU round should be better delineated. In addition, information on the hand-held instruments was not provided in the survey work plan. Consideration should be given to using an instrument that will be more sensitive than the Eberline SPA-3 to more easily detect DU rounds at depths deeper than 10 inches. The MDC for the hand-held instrument should be calculated and compared with the information in Table 2.

The survey work plan does not specifically address radiation protection other than estimating the dose to range workers of approximately 0 mrem per year. This survey and recovery work should be conducted under an appropriate radiation safety program approved by the Navy. This would include personnel dosimetry, monitoring, and contamination control. Protective measures, such as wearing gloves, using tongs, and limiting handling time, should be implemented. In addition, acceptable methods for storing the DU rounds that are collected also should be indicated.

The survey work plan notes that basic statistical quantities will be calculated. It is not clear from the information provided what these quantities are or how they will be used in the decision making process. In addition, it is not clear to what extent quality assurance will be provided for the radiofrequency transmission of data, to verify that data is not corrupted during transmission.

CONCLUSIONS AND COMMENTS

The proposed detection system and survey methods appear to be sufficient to detect DU rounds on the surface. While MARSSIM [Ref 1] is not strictly applicable to this type of survey, if the Navy desires to use the results for unrestricted release, it should consider the framework of the MARSSIM process to the extent practical. This would include consideration of the development of data quality objectives, estimation of MDC, and interpretation of survey data. Based on certain assumptions, we estimate that rounds buried deep (about ten inches or more) will be difficult to detect. We recommend that the Navy consider conducting, prior to beginning the actual survey, a "mock" survey at the site. The purpose of the "mock" survey would be to demonstrate at what depth the scanning equipment can detect the DU rounds. This "mock" survey could consist of burying several intact and partial DU rounds and various depths and scanning the area to determine the system response. Information from the "mock" survey can be used to more accurately estimate the detector efficiency, MDCR, and response for the NAVTRACK system and hand-held instruments.

In summary, although our review revealed some technical concerns, we conclude that survey work plan is adequate to detect the DU rounds. Because our analysis relied on several assumptions, it is advisable that Region II staff be present during the "mock" survey. In addition, Region II staff should be present at the beginning of the actual survey and periodically afterwards, if deemed necessary, to evaluate the effectiveness of the survey. After the survey is completed and the actual number of rounds that remain has been determined, the Navy should consider submitting a report documenting the results. Moreover, rounds not retrieved should be addressed in any decommissioning plan. It is advisable that the NAVY meet with NMSS and Region II staff to discuss the scope and details of a decommissioning plan before making a formal submittal. This will assist in streamlining the review by reducing the number of clarification questions that may result. If all the DU rounds are recovered, the site would be considered acceptable for unrestricted release in accordance with Subpart E and no additional submittal would be required.

REFERENCES

1. USNRC, " Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," NUREG-1575, U.S. Nuclear Regulatory Commission, December 1997.

2. U.S. Army, "Radiological Sources of Potential Exposure and/or Contamination, TG-238," U.S. Army Center for Health Promotion and Preventative Medicine, June 1999.

3. Kocher, David C., "Radioactive Decay Data Tables, A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments," U.S. Department of Energy, April 1981.

4. USNRC, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," NUREG/CR-1507, U.S. Nuclear Regulatory Commission, December 1997.